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Interactive comment on "The Geodynamic World Builder: a solution for complex initial conditions in numerical modelling" *by* Menno Fraters et al.

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We would like to express our gratitude to the reviewer for the very careful reading of our manuscript. Peer review makes scientific articles better, and this applies to this one as well – thank you!

The revised paper has been added as a supplement.

[1] This paper introduces an interesting tool to support the modelling of complex geometries, temperature distributions and, more in general, initial conditions to numerical models. The paper explains the approach to the problem and the algorithm choice and the coding strategy, then proceed to illustrates some workflows to embed the tool in

existing geodynamics computational frames. I find this tool very helpful and timely and I am confident our community could benefit from using it. I have recommendations the Authors could consider, listed below. The paper reads well and I will not comment on the form, yet I would suggest some more explanation in the content: while I understand that the ropes are likely explained in the documentation, a minimum amount of information should be provided here to warrant a separated scientific paper, unless this is intended as a technical report.

Thank you for your kind words. We will be happy to expand the explanations as suggested on the methods used in the paper or in appendices. In general when writing the paper we have chosen to keep the focus of the paper on explaining the concepts instead of implementation details, since the exact details of implementation may change over time, while the proposed concepts should stay the same.

[2] More information is needed on the thermal structure of the slabs. I understand this is derived from McKenzie, 1970, yet I'd recommend the equation solved is presented - briefly - in the paper. This would help the reader understand some critical aspects, such as the velocity assumed to advect the temperature field, if any, whether this solution allows for diffusion or not. This is not clear from figure 1, which seems a bit odd. In principle, this is not a problem, since energy equations routinely solve for both advection and diffusion, in the simplest formulation, yet, strong temperature (and, hence, viscosity) gradients affect the performance of some solvers (mg, for instance) as well as some mesh topologies (e.g., mesh refinements). Some information might help the seamless integration of this tool in the numerical codes. Additionally, this comment applies to the offset ridge in figure 3, where strong horizontal temperature gradient result along the offset zones.

We have added the McKenzie equation, with a short explanation on the implementation in section 2.1.4. As can be seen in the equation, the advection velocity enters as the plate velocity v in the Reynolds number (equation 2).

Concerning the issue of sharp transitions in the initial temperature distribution: this in general not a problem in application codes because thermal diffusion will quickly smoothen such transitions. If necessary because of potential instabilities application codes can first subject the initial temperature field to a small number of timesteps where only thermal diffusion operates to smoothen the temperature field, before starting the convecting flow.

For this reason the GWB does not currently implement diffusion of the temperature field. It is viewed by the authors as not a core task of the GWB, better performed by geodynamic model codes. Futhermore, in the example cases and in the production geodynamic modelling of 3d subduction zones which the authors did, diffusion by the GWB was not needed.

It is technically possible to add a temperature plugin/model to the GWB which computes diffusion locally for every point, but that would have to construct its own local grid and diffuse over that. This could be added if there is a strong demand from users, but it will make the every query to the world builder a lot more expensive. For now, the authors view this as a function which is more logical (and more efficient) to perform within the geodynamic modelling software used by the user.

We agree that the explanation in the paper on this topic can be improved, and have done so in the discussion.

When we added the equation we noticed two problems in the code computing the McKenzie 1970 temperature model. The problems are described in https://github.com/GeodynamicWorldBuilder/WorldBuilder/pull/125. When the problems were fixed we noticed that the results of the tester had only changed between about a degree and a few tens of degrees. In practice the difference is not noticeable, as is shown in the figure below. We therefore only updated the stand-alone examples which contain subducting plates of section 3.1, and have not re-run the computations. We also took another look at the examples we show and noticed that the 2D subduction examples in section 3.1.1

are very similar to the SEPRAN example in that they both are a ridge with a subducting and overriding plate where the temperatures are defined by a linear temperatures. To be a bit more diverse in the examples we now instead use the adiabatic temperature to define the mantle and lithosphere temperatures instead of a constant temperature.

[3] More in general, the way lateral variations are handled remains a bit unclear. In principle, one could use blocks where the properties are piecewise constant, yet, this is hardly a natural case and might prompt unwanted inaccuracy in the numerical solution. Perhaps a simple "smoothing" parameter could be considered, as opposed to a proper solution of the (temperature/concentration/material) diffusion equation, which can be done numerically by the preferred code.

We agree that continuous lateral variations are not well parameterized yet in the GWB, and that it would add a lot of value to the user in making complex model. There are different ideas of how to best do this, but have not yet been implemented. Since there are already some options (with a little bit of work) in which an approximation of it is possible and we feel that the current state of the GWB is already a great improvement over what is available, we believe that these kind of new features and improvements can be added after the publication. For the remark about smoothing see the answer to [2].

[4] I find the treatment of the tectonic provinces appealing, although I'd recommend some more focus on the subduction zone. From my experience, in both the mechanical and thermo-mechanical approaches, a control on the interface is critical. While non-linearities in the upper plate do reduce the coupling along this interface, this might not happen at the inception of subduction, where the available pull forces are low, whence the use of "weak zones" to ease subduction. Indeed, this might not be the case of the model in fig.5, yet in three-dimension, where computational cost is at a premium, allowing alternative strategies is important. Likely a back arc zone can be imposed with

a thinned area with a piecewise constant thickness, although a more flexible strategy is in order, here

To reduce the coupling one can add a compositional layer at the top of the slab and tune its rheology(e.g. Quinquis et al, tectonophysics 497, 2011). If one want to have a controllable layer on the other side, a fault layer with the desired properties can be added before the slab is added.

Besides defining a piecewise constant thickness, one can also use the subducting plate, set it to an adiabatic temperature and let it start at a certain depth to carve out the complex 3d shape at the bottom of the lithosphere you want. But this is indeed an area where there is still a lot of room for improvement (like in the answer to question [3]).

[5] Last, but not least. I find that this tool's great potential likely resides in the embedding of realistic datasets. Perhaps the Authors have some example or some idea on workflows using datasets, such as slab 2.0, populating the thermal field in a slab defined by the Benioff zone, or perhaps embedding oceanic lithosphere age dataset into the ridge model, for instance.

We agree that this is one of the future features which could add a lot of value to the GWB. We did actually investigate slab 2.0, but we found that we were missing information in the dataset such as distance from the top of the slab and distance from the beginning of the slab. We also found that not all slabs where present or complete in this dataset. This may of course be resolved in the future for this dataset. We are also very interested in adding ways to use tomography datasets to define temperature in the mantle although we wish to proceed here with caution before releasing such features.

Please also note the supplement to this comment:
https://www.solid-earth-discuss.net/se-2019-24/se-2019-24-AC1-supplement.pdf

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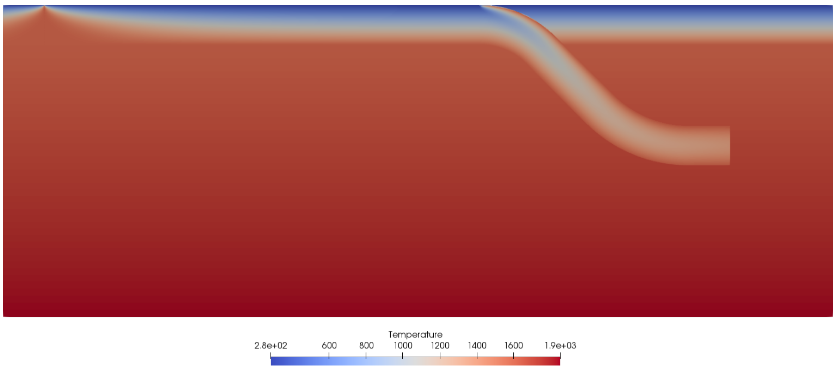

Fig. 1. Temperature field with old McKenzie temperature model implementation for figure 1 in unrevised paper.

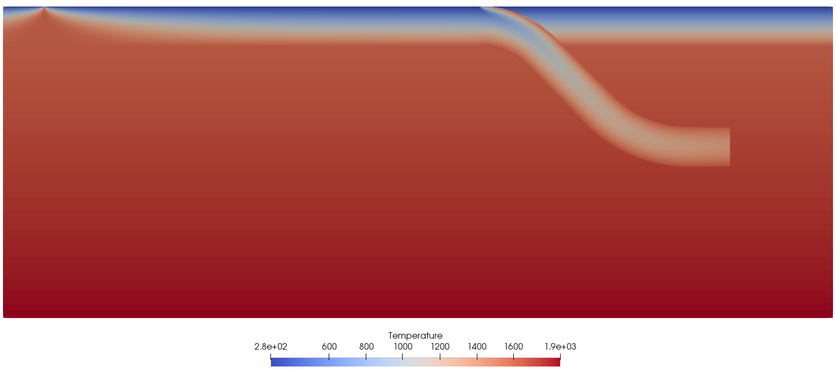

Fig. 2. Temperature field with new McKenzie temperature model implementation for figure 1 in unrevised paper.